Thermal Conductivity.

Read the following account of an experimental investigation and then answer the questions at the end.

The results below were obtained during an experiment to determine the thermal conductivity of aluminium in the form of a cylindrical rod 12·8 mm in diameter and 1·60 m long. The central 0·100 m of the rod was surrounded by a thin layer of mica to act as an electrical insulator, wound with resistance wire to form a heating coil and then surrounded by a thick layer of a good thermal insulator. The rod was arranged horizontally, being supported only at the centre and extreme ends so that air circulated freely round the exposed parts of the rod. Shallow saw cuts were made at 50 mm intervals along the rod so that a thermocouple could be inserted in a cut to determine the rod temperature at various distances from the heater.

A constant current I of 1·50 A was passed through the heater coil. After an hour the temperatures at points along the rod were found to be steady and the potential difference V across the heater coil was measured to be 33 V. The temperature at various points along the rod was then measured; the results are shown in the table below. Measurements were taken on one side of the heater only, distances x being measured from the nearer end of the heated section and excess temperatures θ being measured relative to the temperature of the surrounding air.

Distance from heated section x/m	*Excess temperature* θ/K
0·050	170
0·100	132
0·150	104
0·200	83
0·250	65
0·300	51
0·350	40
0·400	31
0·450	24
0·500	19
0·550	15
0·600	12
0·650	9

It can be shown that if the rate of loss of heat per unit area from the surface of the rod is proportional to the excess temperature θ, then

$$\log \theta = \log \theta_0 - 0{\cdot}434\lambda x$$

where θ_0 is the excess temperature when $x=0$, and λ is a constant.

Questions

6. Plot a graph with excess temperature θ as ordinate and distance from the heater x as abscissa. Determine the slope s of the graph at a suitable point and calculate s/θ at this point.

(11 *marks*)

7. Plot a second graph with log θ as ordinate and x as abscissa and from it determine a value for λ.

(10 *marks*)

8. The rate of supply of heat energy to the rod is VI. Assuming that no heat is lost except from the exposed surface of the rod, this should equal $4\pi r E\theta_0/\lambda$ where r is the radius of the rod and E is the rate of loss of heat per unit area surface for each degree excess temperature.

Obtain the best estimate you can for θ_0 and hence calculate E.

(6 *marks*)

9. The thermal conductivity K of the material of the rod is $2E/\lambda^2 r$. Calculate K.

(3 *marks*)

THERMAL CONDUCTIVITY

DISTANCE FROM HEATED SECTION x / m	XS TEMP θ / K	LOG θ / K
0·050	170	2·230
0·100	132	2·121
0·150	104	2·017
0·200	83	1·919
0·250	65	1·813
0·300	51	1·708
0·350	40	1·602
0·400	31	1·491
0·450	24	1·380
0·500	19	1·279
0·550	15	1·176
0·600	12	1·079
0·650	9	0·954

6) GRADIENT @ $x = 0{\cdot}39\,m$

$$\frac{-94\,(K)}{0{\cdot}585\,(M)} = \underline{-160{\cdot}7\ Km^{-1}}$$

7) $$\log\theta = \log\theta_0 - 0{\cdot}434\lambda x.$$

$$y = C + M \quad x$$

$C = \log\theta_0$

$M = -0{\cdot}434\lambda$

GRADIENT OF GRAPH $\log\theta$ vs x.

$$\frac{-1.54}{0.72} = -2.134\,m^{-1}$$

intercept $y = 2.34$.

so $C = 2.34 = \log\theta_0 = \underline{\underline{\theta_0 = 218.8^\circ}}$

$m = -2.134 = -0.434\lambda$

$\underline{\underline{\lambda = 4.917\,m^{-1}}}$

(8) $VI = 4\pi r E \theta_0 / \lambda$

$$E = \frac{VI\lambda}{4\pi r \theta_0}$$

$V = 33\,V.$

$I = 1.5\,A$

$\lambda = 4.917\,m^{-1}$

$\theta_0 = 218.8\,K$

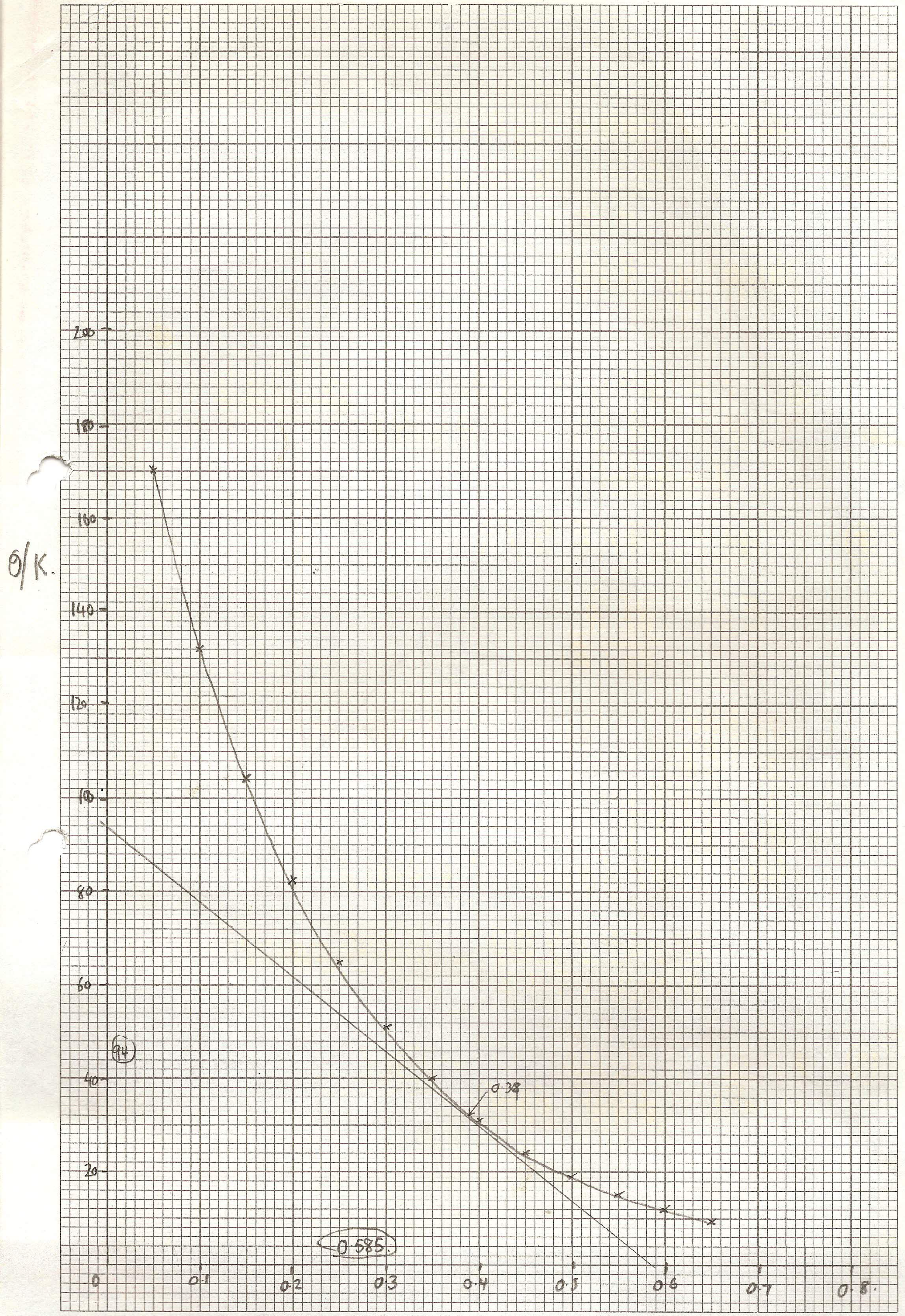
$4\pi r = 4 \times \pi \times 6.4\times10^{-3} = 0.0804\,m$

$$\frac{33 \times 1.5 \times 4.917}{0.0804 \times 218.8} = \underline{\underline{13.835\,J\,m^{-2}\,K^{-1}}}$$

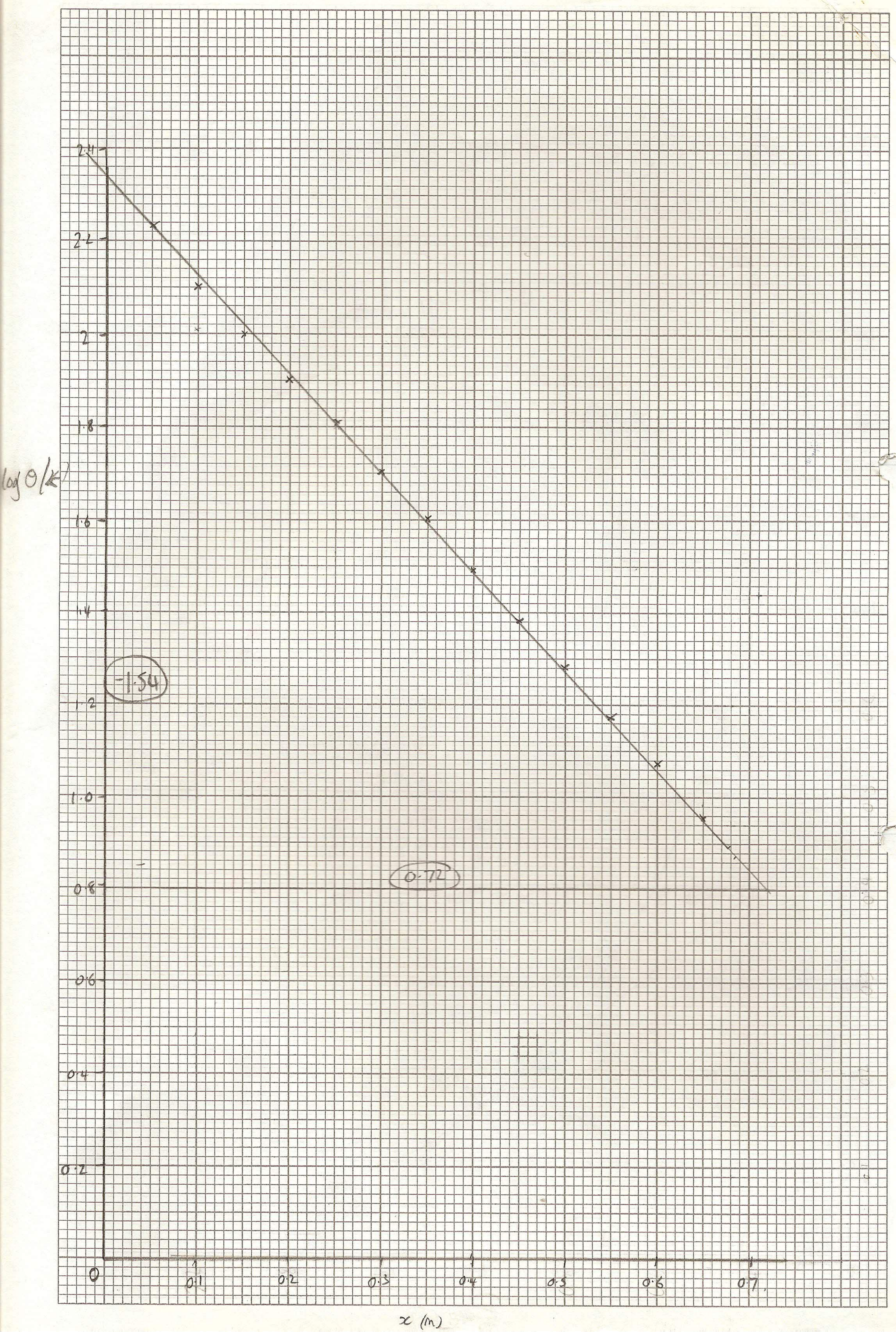
(9) $K = \frac{2E}{\lambda^2 r} = \frac{2 \times 13.85}{(4.917)^2 \times 6.4\times10^{-3}} = \underline{\underline{178.8\,J\,m^{-1}\,K^{-1}}}$

EVERY SECOND

WATTS



θ/K.
200
180
160
140
120
100
80
60
40
20
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8.
94
0·38
0·585


log θ/K
2.4
2.2
2
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
-1.54
0.72
0.1
0.2
0.3
0.4
0.5
0.6
0.7
x (m)